

average roughness Ra of the film is about 0.45 nm when the substrate is maintained at 550 °C and processed under a pressure of 0.3 Torr.

5 On the other hand, the average roughness Ra of a gate insulating film for MISFET is required to be smaller than or equal to 0.2 nm when the gate length thereof is 0.1  $\mu$ m or less.

#### Summary of the Invention

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Accordingly, the present invention strives to provide a new and useful film forming method capable of solving all of the aforementioned problems.

15 Specifically, it is an objective of the present invention to provide a film forming method capable of reducing a surface roughness of a dielectric film when forming the dielectric film through a MOCVD method.

20 It is another objective of the present invention to provide a method for forming a dielectric film by using a metal organic CVD method comprising, the steps of: supplying a metal organic compound into a processing vessel having therein a substrate to be processed; and forming a dielectric film on the substrate, wherein the dielectric film forming step includes: a first step of depositing, in  
25 the processing vessel, the dielectric film under a first condition so as to allow a residence time of the metal

organic compound to extend to a first value; and a second  
step for further depositing the dielectric film under a  
second condition so as to allow the residence time of the  
metal organic compound to extend to a second value smaller  
5 than the first value.

When the high-k dielectric film such as a  $\text{HfO}_2$  film or  
a  $\text{ZrO}_2$  film is formed through the MOCVD in accordance with  
the present invention, the surface roughness of the film can  
be controlled. At the same time, deposition of decomposed  
10 and/or partially decomposed materials of the metal organic  
compound on a showerhead or the like can be suppressed.

#### Brief Description of the Drawings

15 The above and other objects and features of the  
present invention will become apparent from the following  
description of preferred embodiments given in conjunction  
with the accompanying drawings, in which:

Fig. 1 shows the structure of a MOCVD apparatus used  
20 in accordance with a first preferred embodiment of the  
present invention;

Fig. 2 illustrates a relationship between the film  
thickness and the substrate temperature of a  $\text{HfO}_2$  film, the  
processing pressure being a parameter;

25 Fig. 3 describes a relationship between the film  
thickness and the processing pressure of a  $\text{HfO}_2$  film, the

while setting that in step 2 to be large, which can be  
garnered from the equation given above. The residence time  
can also be controlled by setting the flow rate of a carrier  
gas or oxygen gas at a small value in the process of step 1  
5 and then increasing the flow rate thereof in the process of  
step 2.

[Second preferred embodiment]

Figs. 11A to 11E provide a manufacturing process of a  
10 semiconductor device in accordance with a second preferred  
embodiment of the present invention.

Referring to Fig. 11A, a base oxide film 42 composed  
of a  $\text{SiO}_2$  film or a  $\text{SiON}$  film having a film thickness of 1  
nm or less is formed on a silicon substrate 41 by performing  
15 a radical oxidization treatment using, e.g., a UV excited  
oxygen radical, or by performing a plasma radical nitration  
after the radical oxidization treatment. Then, in the  
process of Fig. 11B, a metal oxide film 13 such as  $\text{HfO}_2$  or  
 $\text{ZrO}_2$  is formed in the two step process as previously  
20 described in Fig. 8 on the base oxide film 42 through a  
metal organic chemical vapor deposition (MOCVD) method with  
a metal organic material such as tetra(tert-butoxy)hafnium  
or tetra(tert-butoxy)zirconium at a substrate temperature of  
450 - 600 °C.

25 Thereafter, in the process of Fig. 11C, a polysilicon  
film 44 is deposited on the metal oxide film 43. Although

What is claimed is:

1. A method for forming a dielectric film by using a metal organic CVD method, comprising the steps of:

5 supplying a metal organic compound into a processing vessel having therein a substrate to be processed; and

forming a dielectric film on the substrate,

wherein the dielectric film forming step includes:

10 a first step of depositing, in the processing vessel, the dielectric film under a first condition so as to allow a residence time of the metal organic compound to extend to a first value; and

15 a second step for further depositing the dielectric film under a second condition so as to allow the residence time of the metal organic compound to extend to a second value smaller than the first value.

2. The method for forming a dielectric film of claim 1, wherein, in the first step, the processing pressure in the processing vessel is set at a first processing pressure, and, 20 in the second step, the processing pressure in the processing vessel is set at a second processing pressure which is lower than the first processing pressure.

25 3. The method for forming a dielectric film of claim 1, wherein, in the first step, the flow rate of a carrier gas

or oxygen gas supplied into the processing vessel is set at a first flow rate, and, in the second step, the flow rate of the carrier gas or the oxygen gas is set at a second flow rate which is greater than the first flow rate.

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4. The method for forming a dielectric film of claim 1, wherein the dielectric film is a crystalline film, and in the first step, crystalline nuclei of the dielectric film are formed on the substrate.

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5. The method for forming a dielectric film of claim 1, wherein the metal organic compound is an organic compound containing Hf or Zr, and the dielectric film is a  $\text{HfO}_2$  film or a  $\text{ZrO}_2$  film.

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6. The method for forming a dielectric film of claim 1, wherein the metal organic compound is tetra(tert-butoxy)hafnium, and the residence time is set to exceed 0.25 second in the first step and to be less than 0.25 second in the second step.

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7. The method for forming a dielectric film of claim 6, wherein, in the first step, the processing pressure in the processing vessel is set to exceed 133 Pa, and in the second step, the processing pressure in the processing vessel is set at 133 Pa or below.

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8. The method for forming a dielectric film of claim 6,  
wherein, in the first step, the processing pressure in the  
processing vessel is set at 200 - 400 Pa, and in the second  
step, the processing pressure in the processing vessel is  
5 set at about 40 Pa or below.

9. The method for forming a dielectric film of claim 6,  
wherein the first and the second steps of the dielectric  
film forming step are performed at a temperature of 450 °C  
10 or higher.

10. The method for forming a dielectric film of claim 6,  
wherein the first and the second steps of the dielectric  
film forming step are performed at a temperature of about  
15 550 °C.